(54) [Title of the Invention] IMMERSION EXPOSURE APPARATUS

(57) [Abstract]

[Problem] To provide an immersion exposure apparatus that does not cause the degradation of its image forming performance.

[Solution] An immersion exposure apparatus has a projection optical system PL for exposure-transferring of a pattern Pa, on a reticle R, onto a wafer W. In the immersion exposure apparatus, at least part of working distance L between the wafer and the lens surface Pe closest to the wafer in the projection optical system is filled with a liquid LQ through which exposure light IL passes. The immersion exposure apparatus is so constructed that the working distance will meet the following relation: $L \leq \lambda/(0.3 \times |N|)$, where L is the length of the working distance, λ is the wavelength of the exposure light IL, and N (1/°C) is the temperature coefficient of the refractive index of the liquid LQ. In addition, pure water with an additive added in it to reduce the surface tension of the pure water or enhance the interface activity of the pure water is used as the liquid LQ.

[Claims]

[Claim 1] An immersion exposure apparatus, which has a projection optical system for exposure transferring of a patternon a reticle, onto a wafer, and in which at least part of working distance between the wafer and the lens surface closest to the wafer in the projection optical system is filled with a liquid through which exposure light passes, the immersion exposure apparatus characterized in that the working distance will meet the following relation:

$$L \leq \lambda / (0.3 \times |N|),$$

where L is the length of the working distance, λ is the wavelength of the exposure light IL, and N (1/°C) is the temperature coefficient of the refractive index of the liquid LQ.

[Claim 2] An immersion exposure apparatus, which has a projection optical system for exposure-transferring of a pattern, written on a reticle, onto a wafer, and in which at least part of working distance between the wafer and the lens surface closest to the wafer in the projection optical system is filled with a liquid through which exposure light passes, the immersion exposure apparatus characterized in that pure water with an additive added in it to reduce the surface tension of the pure water or enhance the interface activity of the pure water is used as the liquid.

[Claim 3] The immersion exposure apparatus according to claim 1 or 2, wherein the length L of the working distance is 2 mm or less.

[Claim 4] The immersion exposure apparatus according to claim 1, 2, or 3, wherein the reticle and the wafer are so arranged that they can be scanned synchronously at a constant speed with a speed ratio corresponding to the magnification of the projection optical system.

[Claim 5] The immersion exposure apparatus according to claim 1, 2, 3, or 4, wherein light in the ultraviolet band is used as the exposure light.

[Claim 6] The immersion exposure apparatus according to claim 1, 2, 3, 4 or 5, wherein the optical surface of the front optical element closest to the wafer side in the projection optical system is formed flat, the lower end face of a lens barrel holding the front optical element is formed flush with the optical surface, and the outer circumferential face at the lower end of the lens barrel is chamfered.

[Claim 7] The immersion exposure apparatus according to claim 6, wherein the front optical element is a parallel flat plate.

[Claim 8] The immersion exposure apparatus according to any one of claims 1 through 7, wherein the wafer is held by a holder table, a wall is provided around the perimeter of the upper face of the holder table so that the liquid can be filled in the working distance, a liquid supply unit is provided inside the holder table so that the liquid can be supplied and recovered, and thermoregulators are provided in both the holder table and the liquid supply unit.

[Claim 9] The immersion exposure apparatus according to any one of claims 1 through 7, wherein the wafer is held by a wafer chuck, a wall is provided around the perimeter of the upper face of the wafer chuck so that the liquid can be filled in the working distance, at least three pins are provided through the wafer chuck, and an elevation driving device is provided to enable the pins to lift up the wafer from the wafer chuck.

[Claim 10] The immersion exposure apparatus according to any one of claims 1 through 7, wherein the wafer is held by a wafer chuck, a wall is provided around the perimeter of the upper face of the wafer chuck so that the liquid can be filled in the working distance, at least three pins are provided through the wafer chuck, and an elevation driving device is so provided that the upper end of the wall of the wafer chuck can be lower than the lower end of the projection optical system.

[Claim 11] The immersion exposure apparatus according to any one of claims 1 through 10, wherein a liquid sealing door is provided in a portion of the wall to freely open or close in order to avoid interference with the lower end part of the projection optical system.

[Claim 12] The immersion exposure apparatus according to any one of claims 1 through 11, wherein a mirror for an interferometer is attached to the side face of the projection optical system, and protection means is provided for separating a light beam incident on and reflected from

the mirror from vapor generated from the liquid.

[Detailed Description of the Invention]

[0001]

[Field of the Invention] The present invention relates to an exposure apparatus for printing a pattern on a reticle, onto a wafer through a projection optical system, and particularly to an immersion exposure apparatus.

[0002]

[Description of the Prior Art] clearance between the last or front lens surface of an optical system and an image surface is called working distance. The working distance of a projection optical system in the conventional exposure apparatus or exposure apparatus is filled with air. It is common practice to take a working distance of 10mm or more for some reason such as to include an autofocus optical system. On the other hand, with ever increasing demand for finer patterns to be transferred to a wafer, it is necessary to make the exposure wavelength shorter or increase the numerical aperture. However, since there are restrictions on the types of glass materials that allow light having a short wavelength to pass through, immersion type exposure apparatus have been proposed in which the working distance is filled with a liquid to increase the numerical aperture and hence make the exposed pattern finer.

[0003] The immersion type exposure apparatus could cause an uneven distribution of refractive indexes due to a temperature distribution of the liquid interposed in the

working distance. Therefore, the following techniques have been proposed as measures against the degradation of image forming performance caused by liquid temperature changes: namely, (A) a technique for stabilizing temperature through a liquid temperature stabilizing mechanism as disclosed in FIG. 3 of US Patent No. 4,346,164,or for making temperature uniform using a vibration-agitator mechanism as disclosed in Japanese Patent Laid-Open No. 06-124873; and (B) a technique, as also disclosed in Japanese Patent Laid-Open No. 6-124873, for measuring the temperature or refractive index of the liquid using a liquid temperature monitoring mechanism to feed it back for temperature control.

[0004]

[Problem to be Solved by the Invention] However, since there has been no discussion regarding the degree of temperature stabilization from a practical perspective to implement the technique (A), this technique actually requires high accuracy of temperature control, as will be described below, which is far from practical. On the other hand, it is also hard to say that the technique (B) is effective because what most affects the image forming performance is the unevenness of temperature. Thus, no conventional techniques for immersion exposure apparatus make direct reference to the restrictions on the optical parameters of the projection optical system such as the working distance, and the immersion technology hardly allows for its peculiarities at present. It is therefore an

object of the present invention to provide an immersion exposure apparatus, which makes it easy to control the temperature of a liquid filled in the working distance to prevent the degradation of image forming performance.

[0005]

[Means for Solving the Problem] The present invention has been made to solve the above-mentioned problem, that is, to provide an immersion exposure apparatus, which has a projection optical system for exposure-transferring of a pattern on a reticle, onto a wafer, and in which at least part of working distance between the wafer and the lens surface closest to the wafer in the projection optical system is filled with a liquid through which exposure light passes, the immersion exposure apparatus characterized in that the working distance meets the following relation:

$L \leq \lambda / (0.3 \times |N|)$

where L is the length of the working distance, λ is the wavelength of the exposure light, and N (1/°C) is the temperature coefficient of the refractive index of the liquid. The immersion exposure apparatus is also characterized in that the liquid used is pure water with an additive added in it to reduce the surface tension of the pure water or enhance the interface activity of the pure water.

[0006] The following describes the operation of the present invention. If the distance from the glass surface at the tip end of the projection optical system to an imaging

plane, that is, if the working distance is L, the width of a temperature distribution of the medium filled in the working distance L is ΔT, the aberration of the imaging wavefront caused by the temperature distribution ΔT is ΔF, and the temperature coefficient of the refractive index of the liquid is N, the following expression (1) is approximately established:

$\Delta F = L \times |N| \times \Delta T$ ...(1)

[0007] It is assumed that a temperature distribution of about 0.01°C exists in the temperature distribution ΔT of the medium even though temperature is controlled by all means in order to keep it uniform. Therefore, at least the following imaging wavefront aberration ΔF is considered to exist:

$\Delta F = L \times |N| \times 0.01°C$ ...(1a)

where N is a value representing the temperature coefficient of the refractive index in a unit of 1/°C.

[0008] The value N of the temperature coefficient of the refractive index varies greatly between liquid and air. For example, for air, $N=-9\times10^{-7}$/°C, and for water, $N-8\times10^{-5}$/°C, that is, the difference is almost 100 times. In general, the working distance L of a projection optical system in a reduction projection exposure apparatus is L>10 nm. Even if L=10 nm, the imaging wavefront aberration ΔF becomes as follows:

For air, $\Delta F = 10\text{mm} \times |-9\times10^{-7}/°C| \times 0.01/°C = 0.09$ nm

For water, $\Delta F = 10\text{mm} \times |-8\times10^{-5}/°C| \times 0.01/°C = 8.0$ nm

[0009] Therefore, it is preferable that the imaging wavefront aberration ΔF be generally equal to or less than 1/30 of the exposure wavelength λ, that is, it should meet the following relation:

$\Delta F \leq \lambda/30$ ...(2)

For example, when an ArF excimer laser having a wavelength of 193 nm is used as the exposure light, $\Delta F<6.4$ nm is desirable. In the case of using water as the medium filled in the working distance, if the working distance L is L>10 mm as in the conventional, the generation of imaging wavefront aberration due to the temperature distribution of the medium is too much, resulting in practical difficulties.

[0010] From the expressions (1a) and (2), the following expression is obtained:

$L \leq \lambda/(0.3 \times |N|)$ ...(3)

Therefore, if the expression (3) is satisfied, an immersion exposure apparatus equipped with a projection optical system that reduces the wavefront aberration caused by the temperature distribution in the immersion liquid to 1/30 or less of the exposure wavelength under the conditions of feasible temperature stability (temperature distribution) can be obtained. As described above, according to the present invention, an upper limit is set on the length of an optical path to mitigate the requirements for a temperature distribution by paying attention to the fact that the amount of wavefront aberration generated when the exposure light passes through the medium having the

temperature distribution depends on the product of the amount of temperature distribution and the length of the optical path in the medium. This makes it possible to put an immersion exposure apparatus to practical use at a feasible level of temperature control of the immersion liquid.

[0011]

[Embodiments of the Invention] The following describes some preferred embodiments of the present invention.

[0012]

[Description of First Embodiment] FIG. 1 shows the overall structure of a projection exposure apparatus or exposure apparatus, according to a first embodiment of the present invention. Here, the projection exposure apparatus is a lens-scanning type projection exposure apparatus, which scans a reticle R and a semiconductor wafer W relative to a reduction projection lens system PL while projecting a circuit pattern on the reticle R to the wafer W through the projection lens system PL having circular image fields telecentrically formed on both the object side and the image side. In FIG. 1, an illumination system 10 includes an ArF excimer-laser light source (not shown) emitting pulsed light having a wavelength of 193 nm, a beam expander (not shown) for shaping the cross section of the pulsed light from the light source, an optical integrator (not shown) such as a fly-eye lens for producing a secondary light-source image (a collection of plural point sources)

from the shaped pulsed light incident on it, a condenser lens system (not shown) for turning the pulsed light from the secondary light-source image into pulsed illumination light having a uniform luminance distribution, a reticle blind (illumination field stop, not shown) for shaping the pulsed illumination light into a rectangular shape elongated in a direction (X direction) perpendicular to the scanning direction (Y direction) during scanning exposure, and a relay optical system (not shown) that cooperates with a condenser lens system 12 and a mirror 14 shown in FIG. 1 to focus the pulsed light IL from the rectangular opening of the reticle blind on an illuminated area AI of a slit or rectangular shape on the reticle R.

[0013] The reticle R is held by vacuum suction (otherwise, by electrostatic suction or mechanical-fastening) on a reticle stage 16 capable of moving with a large stroke in a one-dimensional direction at a constant speed during scanning exposure. In FIG. 1, the reticle stage 16 is guided to move from side to side (in the Y direction in FIG. 1) on a column structure 19 of the apparatus body, while it is also guided to move in a direction (X direction) perpendicular to the paper surface of FIG. 1. The coordinate position and minute amount of rotation of the reticle stage 16 on the XY plane are measured sequentially by a laser interferometer system 17 projecting a laser beam to a moving mirror (plane mirror or corner mirror) MRr attached to a portion of the reticle stage 16 and receiving

a reflected beam from the moving mirror MRr. Then, a reticle stage controller 20 controls a motor 18, such as a linear motor or voice coil motor, for driving the reticle stage 16 based on the XY coordinate position measured by the interferometer system 17 to control the movement of the reticle stage 16 in both the scanning and non-scanning directions.

[0014] When part of the circuit pattern area on the reticle R is illuminated by the rectangular-shaped pulsed illumination light IL projected through the condenser lens system 12 and the mirror 14, an imaging beam from the pattern in the illuminated area AI is projected and focused on a photosensitive resist layer coated on the surface of the wafer W through the reduction projection lens system PL with a reduction ratio of 1/4. The projection lens system PL is so arranged that its optical axis AX passes through the central points of the circular image fields and is concentric with the optical axes of the illumination system 10 and the condenser lens system 12, respectively. The projection lens system PL consists of a plurality of lens elements made of two types of glass materials, quartz and fluorite, having high transmittance with respect to ultra-violet light having a wavelength of 193 nm. Fluorite is used primarily to form lens elements having positive power. Further, the air in a lens barrel in which the plurality of lens elements of the projection lens system PL are retained is replaced with nitrogen gas to avoid the absorption by

oxygen of the pulsed illumination light having the wavelength of 193nm. The nitrogen-gas replacement is also provided for the optical path from the inside of the illumination system 10 up to the condenser lens system 12 (or the mirror 14) in the same manner.

[0015] The wafer W is held on a holder table WH that draws the back side of the wafer W by suction. A wall LB is provided at a constant height around the entire perimeter of the holder table WH, and the liquid LQ is filled inside the wall LB up to a predetermined depth. The wafer W is held by vacuum suction in a depressed portion on the inner bottom of the holder table WH. Further, an annular auxiliary plate HRS is provided around the inner bottom of the holder table WH to surround the perimeter of the wafer W with a predetermined clearance width. The height of the surface of the auxiliary plate HRS is defined to be approximately equal to the height of the surface of a standard type of wafer W drawn by suction on the holder table WH.

[0016] The auxiliary plate HRS is primarily used as an alternative focus detection surface when the detection point of a focus-leveling sensor is located on the outside of the outer edge of the wafer W. The auxiliary plate HRS can also be used for calibration of an alignment sensor used for relative alignment between a shot area on the wafer W and the circuit pattern on the reticle R, and for calibration of the focus-leveling sensor used when the shot

area is scanned and exposed. However, it is preferable to use a dedicated fiducial mark plate provided separately from the auxiliary plate HRS. In this case, the fiducial mark plate is also mounted on the holder table WH in an immersed state to have substantially the same height as the image projection surface of the projection lens system PL, so that the alignment sensor detects various fiducial marks formed on the fiducial mark plate in the immersed state. An example of methods for calibration of system offsets of the focus sensor using the fiducial mark plate on the table is disclosed, for example, in US Patent No. 4,650,983, and an example of calibration methods for various alignment sensors is disclosed, for example, in US Patent No. 5,243,195.

[0017] In the embodiment, as shown in FIG. 1, since the tip end of the projection lens system PL is immersed in the liquid LQ, the projection lens system PL is designed to render at least its tip end waterproof in order to prevent the liquid from leaking into the lens barrel. The lower face (opposite face to the wafer W) of the front lens element of the projection lens system PL is machined in the shape of a flat surface or a convex surface having an extremely large curvature radius so that the liquid can flow smoothly between the lower face of the lens element and the surface of the wafer W during scanning exposure. Further, in the embodiment, the projection lens system PL is designed, as will be described in detail later, to form

its best imaging plane (reticle conjugate plane) in the immersed state at a position about 2-1 mm from the lower face of the front lens element. Therefore, the thickness of the liquid layer formed between the lower face of the front lens element and the surface of the wafer W is also about 2-1 mm, so that not only can the accuracy of temperature control to adjust the temperature of the liquid LQ be relaxed, but an uneven temperature distribution in the liquid layer can also be prevented.

[0018] The holder table WH is mounted on an XY stage 34 in such a manner to enable translational movements (including rough and fine movements in the embodiment) in the Z direction along the optical axis AX of the projection lens PL and fine tilt movements with respect to the XY plane perpendicular to the optical axis AX. The XY stage 34 moves two-dimensionally in the X and Y directions on a base 30. The holder table WH is mounted on the XY stage 34 through three Z-actuators 32A, 32B, and 32C. Each of the actuators 32A-C is a mechanism consisting, for example, of a combination of a piezoelastic element, a voice coil motor, a DC motor, and a lift cam. When the three Z-actuators are driven in the Z direction by the same amount, the holder table WH can be translated in parallel in the Z direction (focus direction), while when the three Z-actuators is driven in the Z direction by amounts different from one another, the tilt direction and amount of the holder table WH can be adjusted.

[0019] The two-dimensional movement of the XY stage 34 is caused by a drive motor 36, such as a DC motor for rotating a feed screw or a linear motor for generating thrust in a non-contact manner. The drive motor 36 is controlled by a wafer stage controller 35 receiving measured coordinate positions from a laser interferometer 33 for measuring each of X- and Y-positional changes of the reflection surface of a moving mirror MRw fixed to an edge portion of the holder table WH. The overall structure of the XY stage 34 using a linear motor as the drive motor 36 is disclosed, for example, in Japanese Patent Laid-Open No. 8-233964.

[0020] In the embodiment, since the working distance of the projection lens PL is so small that the liquid LQ will be filled in a narrow space of about 2-1 mm between the front lens element of the projection lens PL and the wafer W, it is difficult for an obliquely-incident type focus sensor to project a projection beam of light obliquely from above onto the wafer surface corresponding to the projection field of the projection lens system PL. Therefore, in the embodiment, a focus alignment sensor FAD, including an off-axis type focus leveling detection system (having no focus detection point within the projection field of the projection lens system PL) and a mark detection system for detecting alignment marks on the wafer W in an off-axis manner, is arranged as shown in FIG. 1 around the lower end part of the lens barrel of the projection lens system PL.

[0021] The lower face of an optical element (lens, glass

plate, prism, etc.) attached to the tip of the focus alignment sensor FAD is placed in the liquid LQ, and an alignment illumination beam and a focus detection beam are emitted from the optical element to illuminate the surface of the wafer W (or the auxiliary plate HRS) through the liquid LQ. The focus leveling detection system outputs a focus signal Sf corresponding to an error in the position of the surface of the wafer W relative to the best imaging plane. The mark detection system analyzes a photoelectric signal corresponding to the optical characteristics of each mark on the wafer W to output an alignment signal Sa representing the XY position of the mark or the amount of displacement from the position.

[0022] The focus signal Sf and the alignment signal Sa are sent to a main controller 40. Based on the focus signal Sf, the main controller 40 sends the wafer stage controller 35 driving information best suited to each of the three Z-actuators 32A, B, C. The wafer stage controller 35 controls each of the three Z-actuators 32A, B, C to make focus and tilt adjustments to an actually projected area on the wafer W.

[0023] The main controller 40 also manages the coordinate position of the XY stage 34 based on the alignment signal Sa to align the relative position of the reticle R and the wafer W. Further, when each shot area on the wafer W is scanned and exposed, the main controller 40 performs synchronous control of the reticle stage controller 20 and

wafer stage controller 35 so that the reticle R and the wafer W will move in the Y direction at a constant speed with a speed ratio corresponding to the projection magnification of the projection lens system PL.

[0024] Note that, although the focus alignment sensor FAD is provided in FIG. 1 in one location around the tip end of the projection lens system PL, it is preferable that four focus alignment sensors FAD be provided, two in the Y direction and two in the X direction, across the tip end of the projection lens system PL. In addition, a TTR (Through-The-Reticle) type alignment sensor 45 is provided above the reticle R in FIG. 1 to detect alignment marks formed at the periphery of the reticle R and alignment marks on the wafer W (or fiducial marks on the fiducial mark plate) simultaneously through the projection lens system PL and hence to measure the displacement between the reticle R and the wafer W with a high degree of precision. A measured displacement signal is then sent from the TTR alignment sensor 45 to the main controller 40 for use in positioning the reticle stage 16 and the XY stage 34.

[0025] The exposure apparatus in FIG. 1 performs scanning exposure while moving the XY stage 34 in the Y direction at a constant speed. The following describes the schedule of scan and step movements of the reticle R and the wafer W during the scanning exposure with reference to FIG. 2. In FIG. 2, a front lens group system LGa and a rear lens group system LGb are representative of the projection lens system

PL in FIG. 1, and a projection pupil Ep of the projection lens system PL exists between the front lens group system LGa and the rear lens group system LGb. On the reticle R shown in FIG. 2, a circuit pattern area Pa having a diagonal length longer than the diameter of the circular image field on the object side of the projection lens system PL is formed on the inside of a light-shielding zone SB.

[0026] The area Pa on the reticle R is scanned and exposed to a corresponding shot area SAa on the wafer W by scan-moving the reticle R, for example, in a negative direction along the Y axis at a constant speed Vr while scan-moving the wafer W in a positive direction along the Y axis at a constant speed Vw. In this case, as shown in FIG. 2, the area AI of the pulsed illumination light IL illuminating the reticle R is formed in the shape of a slit or rectangle elongated in parallel with the X direction in the area Pa, with both ends in the X direction located on the light-shielding zone SB.

[0027] A part of the pattern included in the pulsed light illuminated area AI inside the area Pa on the reticle R is formed as an image SI in a corresponding position inside the shot area SAa on the wafer W through the projection lens system PL (the lens systems LGa, LGb). After completion of relative scanning of the pattern area Pa on the reticle R and the shot area SAa on the wafer W, the wafer W is step-moved by a given amount in the Y direction

so that it will come to a scanning start position, for example, to a shot area SAb next to the shot area SAa. During this step-movement, the emission of the pulsed illumination light IL is interrupted. Then, the reticle R is moved in the positive direction along the Y axis with respect to the pulsed light illuminated area AI at the constant speed Vr so that the pattern image in the area Pa on the reticle R will be scanned and exposed to the corresponding shot area SAb on the wafer W while moving the wafer W in the negative direction along the Y axis with respect to the projected image SI at the constant speed Vw, thereby forming an electronic circuit pattern image on the shot area SAb. An example of techniques using pulsed light from an excimer-laser light source for scanning exposure is disclosed, for example, in US Patent No. 4,924,257.

[0028] In the projection exposure apparatus shown in FIGS. 1 and 2, when the diagonal length of the circuit pattern area on the reticle R is smaller than the diameter of the circular image field of the projection lens system PL, the opening shape or size of the reticle blind in the illumination system 10 can be so changed that the shape of the illuminated area AI will coincide with that of the circuit pattern area, enabling the use of the apparatus of FIG. 1 as a step-and-repeat stepper. In this case, the reticle stage 16 and the XY stage 34 stay still relative to each other during exposure of the shot area on the wafer W. However, if the wafer W moves slightly during the exposure,

the slight movement can be measured by the laser interferometer system 33. The reticle stage 16 is controlled and moved slightly in order to perform a tracking correction on the reticle R side so that the slight displacement of the wafer W with respect to the projection lens system PL is compensated. Further, when the shape or size of the reticle blind is changed, a zoom lens system may be so provided that the pulsed light coming from the light source and reaching the reticle blind will converge on a region corresponding to the adjusted opening size in response to the change in the shape or size of the reticle blind.

[0029] As apparent from FIG. 2, since the area of the projected image SI is assumed to have a slit or rectangular shape elongated in the X direction, the embodiment is configured to make the tilt adjustment during scanning exposure exclusively in a rotational direction around the Y axis, that is, only the rolling direction with respect to the direction of scanning exposure. Of course, if the width of the area of the projected image SI in the scanning direction is large enough to require consideration of the flatness of the wafer surface in the scanning direction, the tilt adjustment will be made in a rotational direction around the X axis, that is, the pitching direction, during scanning exposure.

[0030] The state of the liquid LQ in the holder table WH that is a characteristic feature of the exposure apparatus

according to the embodiment will be described below with reference to FIG. 3. FIG. 3 is a partially sectional view from the tip end of the projection lens system PL to the holder table WH. A positive lens element LE1 whose lower face Pe is flat and upper face is convex is fixed at the tip of the projection lens system PL inside the lens barrel. The lower face Pe of the lens element LE1 is so finished that the lower face Pe will be flush with the end face of the tip end of the metallic part of the lens barrel (flush surface finishing), preventing the flow of the liquid LQ from becoming turbulent. An outer corner portion 114, which is a portion to be immersed in the liquid LQ at the tip end of the lens barrel of the projection lens system PL, is chamfered, for example, to have a large curvature as shown in FIG. 3, in order reduce resistance against the flow of the liquid LQ and hence to prevent the generation of an unnecessary vortex or turbulent flow. Further, a plurality of protruding suction faces 113 are formed in a central portion of the inner bottom of the holder table WH to draw the back face of the wafer W by vacuum suction. Specifically, these suction faces 113 assume the shape of an annular zone consisting of a plurality of annular land portions having about 1 mm in height and concentrically formed with a predetermined pitch in the direction of the radius of the wafer W. Then, a groove is cut at the center of each of the annular land portions, and each of the grooves is connected to piping 112 inside the table WH, and

to a vacuum source for vacuum suction.

[0031] In the embodiment, as shown in FIG. 3, the spacing or distance L between the lower face Pe of the lens element LE1 at the tip end of the projection lens system PL and the surface of the wafer W (or the auxiliary plate HRS) is set in the range of about 2-1 mm for the best focus state. Therefore, the depth Hq of the liquid LQ to be filled in the holder table WH can be just two, three, or more times the distance L, and hence the height of the wall LB provided around the holder table WH can be just several to ten mm. Thus, in the embodiment, since the distance L as the working distance of the projection lens system PL is set very small, the total amount of liquid LQ to be filled in the holder table WH can be reduced, thereby making temperature control easy.

[0032] In the embodiment, pure water easy to obtain and handle is used for the liquid LQ. However, note that a slight percentage of aliphatic additive (liquid), which does not dissolve the resist layer of the wafer W and the influence of which on the optical coating of the lower face Pe of the lens element can be ignored, is added to the pure water to not only reduce the surface tension of the pure water but to enhance the interface activity of the pure water. Methyl alcohol or the like having a refractive index approximately equal to that of the pure water is preferably used as the additive. In such a case, even if the methyl alcohol component in the pure water evaporates to vary its

concentration, the total change in the refractive index of the liquid LQ can be minimized.

[0033] The temperature of the liquid LQ is controlled for a target temperature with a constant degree of accuracy. The accuracy of controlling temperature in a relatively easy manner at present is about ±0.01°C. Based on such temperature-control accuracy, the following considers a realistic immersion projection method. In general, the temperature coefficient N_a of the refractive index of air is about -9×10^{-7}/°C, while the temperature coefficient N_q of the refractive index of water is about -8×10^{-5}/°C. In other words, the temperature coefficient N_q of the refractive index of water is about two orders of magnitude larger than that of air. On the other hand, if the working distance is L, the amount of imaging wavefront aberration ΔF caused by the amount of temperature change (temperature unevenness) ΔT in the medium filled in the working distance L is approximately represented as follows:

$\Delta F = L \bullet |N| \bullet \Delta T$

[0034] Here, if normal projection exposure is carried out without the application of an immersion projection method, the amount of wavefront aberration ΔF_{air} under such conditions that the working distance L is 10mm and the amount of temperature change ΔT is 0.01°C is as follows:

$\Delta F_{air} = L \bullet |Na| \bullet \Delta T \approx 0.09$ nm

On the other hand, the amount of wavefront aberration ΔF_{lq} in the case of applying the immersion projection method is

as follows:

$\Delta F_{1q}=L\bullet|N_q|\bullet\Delta T\approx 8$ nm

[0035] In general, it is desirable that the amount of wavefront aberration be about 1/30 through 1/50-1/100 of the wavelength λ used. Therefore, in the case of using the ArF excimer laser, the maximum allowable amount of wavefront aberration ΔF_{max} is defined in the range of 6.43 through 3.86-1.93 nm corresponding to 1/30 through 1/50-1/100 of the wavelength λ generally used, and preferably 1.93 nm or below at 1/100 of the wavelength λ. The heat conductivities of air and water at 0°C are 0.0241 W/mK and 0.561 W/mK, respectively. In other words, water is better heat conductor than air, so that the temperature unevenness in the optical path formed in the water can be reduced compared to that in the air, thereby reducing the fluctuation in the refractive index in the liquid. However, as shown in the expression (3), if the working distance L is about 10 mm, the amount of wavefront aberration ΔF_{1q} generated is far beyond the allowable amount of wavefront aberration ΔF_{max} even if the amount of temperature change ΔT is 0.01°C.

[0036] It follows from the above consideration that the relationship between the amount of temperature change ΔT after taking into account the amount of allowable wavefront aberration ΔF_{max} and the working distance L is from $\Delta F_{max}=\lambda/30\geq L\bullet|N_q|\bullet\Delta T$ to $\Delta F_{max}=\lambda/100\geq L\bullet|N_q|\bullet\Delta T$. Assuming that the amount of temperature change ΔT is 0.01°C, the

wavelength λ is 193nm, and the amount of change N_q in the refractive index of the liquid LQ is -8×10^{-5}/°C, the required working distance (thickness of the liquid layer) L is from 8 mm to 2.4 mm or less. It is desirable that the working distance L be smaller than 2 mm as long as the liquid LQ flows smoothly in the working distance L. Since the embodiment is configured as mentioned above, not only can the temperature control of the liquid LQ be made easy, but the degradation of the projected image induced by a change in wavefront aberration due to a temperature change in the liquid layer can also be prevented, making possible projection exposure of a pattern on the reticle R with an extremely high resolution.

[0037]

[Description of Second Embodiment] Referring next to FIG. 4, a second embodiment of the present invention will be described. This embodiment shows a temperature control method for the liquid LQ, which is also applicable to the first embodiment, and a method of dealing with the liquid LQ at the time of changing the wafer W. Therefore, components in FIG. 4 common to those in FIGS. 1 and 3 are given the same reference numerals and symbols. In FIG. 4, a plurality of suction faces 113 are formed in a wafer loading portion as a circular depressed portion on the inner bottom of the holder table WH. Then an annular groove 51 used for supply and discharge of the liquid LQ is formed around the circular wafer loading portion. Part of the

groove 51 communicates with an external pipe 53 through a passage 52 formed inside the table WH. Further, thermoregulators 50A, 50B such as Peltier elements are embedded directly below the wafer loading portion and the auxiliary plate HRS inside the holder table WH, and temperature sensors are placed in position (preferably at plural positions) on the holder table WH to detect the temperature of the liquid LQ precisely. The thermoregulators 50A, 50B are controlled by a controller 60 in such a manner that the temperature of the liquid LQ detected by the temperature sensors 55 will be kept at a constant value.

[0038] On the other hand, the pipe 53 is connected to a liquid supply unit 64 and a drainage pump 66 through a selector valve 62. The selector valve 62 switches over between a flow path for supplying the liquid LQ from the liquid supply unit 64 to the pipe 53 and a flow path for returning the liquid LQ from the pipe 53 to the supply unit 64 through the drainage pump 66 in response to an instruction from the controller 60. Inside the supply unit 64, a reserve tank (not shown) capable of reserving the total amount of liquid LQ on the holder table WH, a pump 64A for supplying the liquid LQ from the tank, and a temperature controller 64B for keeping the liquid LQ in the tank including the pump 64A at a constant temperature are provided. In the above-mentioned structure, the operation of the valve 62, the pump 64A, the temperature controller

64B, and the drainage pump 66 are centrally controlled by the controller 60.

[0039] In such a structure, when the wafer W is carried to the wafer loading portion of the holder table WH and loaded on the plural suction faces 113 in a pre-aligned state, the wafer is fixed under a reduced pressure through the vacuum suction piping 112 shown in FIG. 3. During this operation, the thermoregulators 50A, 50B continue to be controlled at a target temperature. Then, upon completion of vacuum suction of the wafer W, the selector valve 62 is moved from a closed position to the supply unit 64 side to actuate the pump 64A to fill the temperature-controlled liquid LQ to the inside of the wall LB of the holder table WH by a given amount through the pipe 53, the passage 52, and the groove 51. After that, the selector valve 62 returns to the closed position. Once the exposure of the wafer W is completed, the selector valve 62 is moved from the closed position to the drainage pump 66 side to actuate the drainage pump 66 to return the liquid LQ on the table WH to the reserve tank in the supply unit 64 through the groove 51 and the pipe 53. The temperature of the liquid LQ returned to the tank is controlled precisely by the temperature controller 64B based on a detection signal from a temperature sensor provided in the reserve tank until the next wafer is ready.

[0040] Thus, according to the embodiment, the temperature of the liquid LQ during immersion exposure is controlled by the thermoregulators 50A, 50B in the holder table WH, while

the liquid LQ is recovered into the supply unit 64 during wafer change so that the temperature of the liquid LQ will be controlled in the supply unit 64. This structure has the advantages of making possible wafer change in air and preventing a big temperature change in the liquid LQ. Further, according to the embodiment, even if the temperature of the liquid LQ filled in the holder table WH after wafer change is deviated slightly (e.g., about 0.5°C) from a set temperature, it can reach the set temperature in a relatively short time because the depth of the liquid layer H_q (see FIG. 3) is shallow on the whole, thereby also making it possible to reduce the waiting time until the temperature is stabilized.

[0041]

[Description of Third Embodiment] Referring next to FIG. 5, a third embodiment will be described. FIG. 5 shows a partial cross section of a holder table WH improved from that of FIG. 3. The holder table WH in this embodiment is divided into two parts, namely a wafer chuck 90 for holding the wafer W and a ZL stage 82 moving in the Z direction for focus leveling and performing tilt movement, in which wafer chuck 90 is placed on the ZL stage 82. The ZL stage 82 is provided on the XY stage 34 through three z actuators 32A, 32C (32B not shown). Like in FIGS. 1, 3, and 4, the wall LB, the auxiliary plate HRS, the piping 112 for vacuum suction, and passages 53A, 53B communicating with the pipe 53 for supply and discharge of the liquid LQ (see FIG. 4) are

formed in the chuck 90, respectively. Note here that the passage 53A communicates with the peripheral part of the auxiliary plate HRS inside the wafer chuck 90, while the passage 53B communicates with the downmost part of the wafer loading portion on the inner bottom of the wafer chuck 90. Thus, since the passages for discharging and filling the liquid are formed at two or more positions, it can be quick to take in or out the liquid.

[0042] Further, in the embodiment, three through-holes (only two of them shown) 91 are formed in the central portion of the chuck 90, and three center-up pins (only two of them shown) 83 moving up and down through the through-holes 91, respectively, are provided on a vertically movement driving mechanism 85. The vertically movement driving mechanism 85 is fixed on the side of the XY stage 34. The three center-up pins 83 are to lift up or down the wafer W on the chuck 90 by a given amount from or onto the loading surface during wafer change. When the wafer W is held on the loading surface of the chuck 90 by vacuum suction as shown in FIG. 5, the tip end of each of the center-up pins 83 is located in a position lower than the loading surface of the chuck 90.

[0043] On the other hand, a parallel flat plate CG made of silica glass and fixed perpendicularly to the optical axis AX is attached to the tip end of a sub lens-barrel 80 provided in the tip end of the projection lens system PL used in the embodiment so that the front lens element LE1

(plano-convex lens) will not be immersed in the liquid LQ. In the embodiment, the spacing or distance between the lower face of the parallel flat plate CG and the surface of the wafer W becomes a nominal working distance and is set to 2 mm or less like in the aforementioned embodiments. The attaching surface of the parallel flat plate CG to the sub lens-barrel 80 is waterproofed and nitrogen gas is filled in the sub lens-barrel 80.

[0044] Thus, since the parallel flat plate CG is provided at the tip end of the projection lens system PL, even if the substantial backfocus distance (distance from the front optical element having refractive power to the imaging plane) of the projection lens system PL is about 10 to 15 mm, the working distance L can easily be set to about 1 to 2 mm, enabling the implementation of an immersion projection method with reduced influence of temperature changes in the liquid. Further, the parallel flat plate CG can be retrofitted, part of the surface of the parallel flat plate CG can be polished on the order of a fraction of the wavelength, thus making it easy to correct local slight distortion (or random distortion) in the projected image. In other words, the parallel flat plate CG has both a function as a window to protect the front lens element located at the tip end of the projection lens system PL and a function as a distortion correcting plate. From another point of view, it can be said that the image forming performance of the projection lens system PL including the

parallel flat plate CG is certified, that is, the parallel flat plate CG is consistently a front lens element located at the tip end of the projection lens system PL.

[0045]

[Description of Fourth Embodiment] Referring next to FIG. 6, a fourth embodiment will be described. This embodiment is related to the embodiment shown in FIG. 5 regarding wafer change when the projection optical system having an extremely small working distance is used for an immersion type projection exposure method. In FIG. 6, a reference mirror ML (for X and Y directions) receiving and reflecting a reference beam BSr from the laser interferometer 33 shown in FIG. 1 is fixed in the lower end portion of the lens barrel of the projection lens system PL. In operation, a length measuring beam BSm from the laser interferometer 33 is projected to a moving mirror MRw fixed to an edge portion of the ZL stage 82 as shown in FIG. 5, and the reflected beam is returned to the laser interferometer 33 so that it will interfere with the reflected beam of the reference beam BSr, thereby measuring the coordinate position of the reflection surface of the moving mirror MRw, that is, the XY coordinate position of the wafer W with reference to the position of the reference mirror ML. In the embodiment, the ZL stage 82 is also mounted on the XY stage 34 through the three Z actuators 32A, 32B (32C not shown) in such a manner that it can move in the Z direction and the tilt direction. Note here that the ZL stage 82 is

coupled to the XY stage 34 through leaf springs 84A, 84B (84C not shown) provided at three positions around its perimeter so that it will be supported with extremely high rigidity in the horizontal direction (on the XY plane) with respect to the XY stage 34.

[0046] In the embodiment, the wafer chuck 90 like in FIG. 5 is also provided on the ZL stage 82. A point different from FIG. 5 is that the wafer chuck 90 is configured to move in the Z direction relative to the ZL stage 82 with a relatively large stroke (about 10 to 15 mm) by means of a plurality of Z-direction driving mechanisms 88A, 88B. Unlike the Z actuators 32A, B, C for focus leveling, the driving mechanisms 88A, 88B have only to move the wafer chuck 90 between both ends of the stroke. Therefore, they can be configured to have a simple elevation function using an air cylinder or link mechanism. Further, in the embodiment of FIG. 6, the center-up pins 83 shown in FIG. 5 are fixed on the XY stage 34 without up and down movement. Then, as shown in FIG. 6, when the wafer chuck 90 is lifted to its upmost position, the surface of the wafer W is located 1 to 2 mm from the surface of the front optical element of the projection lens system PL and the end face of each of the center-up pins 83 is slightly (about 2 to 3 mm) lower than the wafer loading face of the wafer chuck 90.

[0047] FIG. 6 shows the above-mentioned structure in a state during exposure of the wafer W. After completion of the exposure operation, the liquid LQ is temporarily

discharged from the wafer chuck 90 in the manner as shown in FIG. 4. Then, once the vacuum suction of the wafer chuck 90 is released, the driving mechanisms 88A, 88B are actuated to lift down the wafer chuck 90 from the position in FIG. 6 to its downmost position. This causes the wafer W to be reloaded on the tip end faces of the three center-up pins 83 while positioning the upper end face of the wall LB around the wafer chuck 90 to be lower than the front end surface of the projection lens system PL (the lower face Pe of the lens element LE1 in FIG. 3 or the lower face of the parallel flat plate CG in FIG. 5). In this state, if the XY stage 34 is moved to a wafer change position, the wafer W is drawn out from the position directly below the projection lens system PL and moved toward a transport arm 95. At this time, since the arm 95 is set to be higher than the upper end face of the wall LB of the wafer chuck 90 and lower than the wafer W on the center-up pins 83, it gets into the downside of the wafer W. Then, the arm 90 transports the wafer W toward a predetermined unload position while lifting the wafer W slightly up under vacuum suction. The way of carrying in the wafer W is exactly opposite to the above-mentioned sequence.

[0048] As shown in FIG. 6, when the structure is of the type in which the laser interferometer 33 projects the reference beam BSr to the reference mirror ML for the projection lens system PL, since a pool of liquid LQ spreads out over the space directly below the optical path

of the reference beam BSr, it is considered that a rise of saturated vapor could cause fluctuation in the optical path of the reference beam BSr. Therefore, in the embodiment, a cover plate 87 is arranged between the optical path of the reference beam BSr and the liquid LQ to block the flow of the rising vapor in order to prevent the fluctuation in the optical path of the reference beam BSr.

[0049] In order to more stabilize the optical path of the reference beam BSr, temperature-controlled clean air may be sent in a direction intersecting the optical path over the cover plate 87. In this case, the cover plate 87 also has a function for preventing a direct air blow for air-conditioning of the optical path to the liquid LQ, thus reducing unnecessary evaporation of the liquid LQ. Alternatively, the entire optical path of the reference beam BSr may be covered with a wind-shielding cylinder instead of such a simple cover plate 87.

[0050]

[Description of Fifth Embodiment] Referring next to FIGS. 7(A) and (B), a fifth embodiment will be described. This embodiment shows a combination of the structure of the holder table WH shown in FIG. 1 with a center-up mechanism (pins 83 and z-driving mechanism 85) shown in FIG. 5, that is, it shows an improved structure of the holder table WH for easy wafer change. FIG. 7(B) is a plan view of the improved holder table WH and FIG. 7(A) is a sectional view taken along the line 7A in FIG. 7(B). It is apparent from

FIGS. 7(A),(B) that the holder table WH is held on the XY stage 34 through three Z actuators 32A, 32C (32B not shown), and three through-holes 91 are provided in the central portion of the holder table WH. Center-up pins 83 moving up and down by means of a driving part 85 penetrate through the through-holes 91, respectively.

[0051] As described above, the height of the downmost end face of the projection lens system PL is just about 2 mm from the surface of the auxiliary plate HRS (wafer W) in its original state. In addition, the upper end of the wall LB provided around the holder table WH is higher than the downmost end face of the projection lens system PL. Therefore, if the XY stage 34 is moved for wafer change to draw out the wafer from the position directly below the projection lens system PL, the width of part of the auxiliary plate HRS will have to be about as large as the diameter of the lens barrel of the projection lens system PL, resulting in an increase in the volume of the holder table WH in which the liquid LQ is filled.

[0052] Therefore, in the embodiment, part of the wall LB of the holder table WH is cut or notched to provide a liquid sealing door DB to freely open or close in the notch portion. The liquid sealing door DB is closed to close the notch portion of the wall LB to seal the liquid while the liquid LQ is being filled as shown in FIGS. 7(A), (B). On the other hand, it is open as indicated by the broken line in FIG. 7(A) while the liquid LQ is being discharged from

the holder table WH. The liquid sealing door DB is configured to be slightly higher than the surface of the auxiliary plate HRS when it is in the open state. Further, an O ring OL is provided in position on the wall side (including the notch portion of the wall LB) corresponding to the body side of the holder table WH that encounters the inner wall of the liquid sealing door DB to ensure sealing performance as shown in FIG. 7(B).

[0053] In such a structure, when the wafer on the holder table WH is changed for another, the liquid LQ is first discharged from the holder table WH before opening the liquid sealing door DB. Then, the XY stage 34 is moved to the right in FIG. 7 so that the wafer is drawn out from the position directly below the projection lens system PL. At this time, the projection lens system PL is located above the liquid sealing door DB that has just been opened. Then, the center-up pins 83 are raised to lift up the wafer to a position higher than the wall LB, thus making it easy to replace the wafer.

[0054] According to the embodiment, the diameter of the wall LB surrounding the perimeter of the holder table WH can be minimized to minimize the total amount of liquid LQ to be filled in the holder table WH. This structure has the advantages of making it easy to manage the temperature of the liquid LQ and minimizing the filling and discharging time of the liquid LQ. In the structure of the fourth embodiment, the liquid sealing door does not need providing

because the wafer chuck is lifted down, but such a liquid sealing door may also be provided in the fourth embodiment.

[0055]

[Description of Sixth Embodiment] Next, FIG. 8 shows a sixth embodiment of the present invention. In the embodiment, a lower case 7 and an upper case 8 are used. A wafer holder 3a for loading a wafer 3 is formed on the inner bottom of the lower case 7. The upper face of the lower case 7 is hermetically closed by the bottom surface of the upper case 8, and the total volume of the lower case 7 is fully filled with an immersion liquid 7a. The upper case 8 is also filled with an immersion liquid 8a so that the last or front lens surface 1a of a projection optical system 1 will be immersed in an immersion liquid 8a.

[0056] Part of the immersion liquid 7a in the lower case 7 is guided to a thermoregulator 6 form an outlet 5 provided on one side of the lower case 7 so that the thermoregulator 6 will regulate the temperature of the immersion liquid 7a. The temperature-regulated immersion liquid 7a is then given back to the lower case 7 from an inlet 4 provided on the other side of the lower case 7, thus circulating the immersion liquid 7a. A plurality of temperature sensors (not shown) are placed at plural positions in the lower case 7 so that the thermoregulator 6 will control the temperature of the immersion liquid 7a in the lower case 7 to be kept constant based on the output of the temperature sensors. The same temperature control mechanism is also

provided for the immersion liquid 8a in the upper case 8.

[0057] In the embodiment, the lower case 7 and the upper case 8 are integrally moved to move the wafer 3. On the other hand, since the immersion liquid in the lower case in which the wafer 3 is housed is substantially closed, this structure are advantageous not only because of its temperature stability but also because it can prevent the occurrence of a pressure distribution due to an unnecessary flow such as a vortex in the immersion liquid. In other words, a pressure distribution in the immersion liquid causes a fluctuation in refractive index and hence the deterioration of the imaging wavefront aberration. However, in the sixth embodiment, since only the pressure distribution in the immersion liquid 8a filled in the upper case 8 causes a problem, the optical path in this section L_8 can be formed short enough to mitigate the influence of the flow of the immersion liquid during wafer movement to such a level not to cause any practical problem.

[0058] In the embodiment, the lower case 7 and the upper case 8 are integrally moved, but only the lower case 7 can be moved while fixing the upper case 8. In such a structure, the immersion liquid 8a in the upper case 8 completely stops its flow. Therefore, it is preferable that the working distance L be so set that the thickness L_7 of the immersion liquid 7a in the lower case 7 will be sufficiently thinner than the thickness L_8 of the immersion liquid 8a in the upper case 8.

[0059]

[Description of Alternative Embodiments] Although the embodiments of present invention are described above, since the working distance of the projection lens system during immersion exposure is extremely small, about 1-2 mm, as shown in FIG. 1, the off-axis type focus alignment sensor FAD is used for focusing on the wafer W. Alternatively, a TTL (Through-The-Lens) type focus detection mechanism as disclosed, for example, in US Patent No. 4,801,977 or 4,383,757, may be provided, which projects a focus detection beam onto the wafer through a peripheral part within the projection field of the projection lens system PL to measure the height or tilt of the wafer surface.

[0060] Further, although the focus alignment sensor FAD shown in FIG. 1 is of an off-axis type that optically detects the alignment marks on the wafer W, this alignment sensor may be of the TTL type that detects the marks on the wafer W through only the projection lens system PL and provided in addition to the TTR alignment sensor 45 in FIG. 1 for detecting the marks on the wafer W through both the reticle R and the projection lens system PL. Furthermore, if the present invention includes a projection optical system for projection exposure under the source of ultraviolet light (having a wavelength of 400 nm or less), it can be applied to any exposure apparatus in the same manner regardless of its structure.

[0061]

[Effects of the Invention] As described above, the present invention provides an immersion exposure apparatus that can ensure sufficient image forming performance in the range of practically feasible temperature control. The present invention also provides the structure of a wafer stage suitable for loading and unloading a wafer in the immersion exposure apparatus.

[Brief Description of the Drawings]

[FIG. 1] It is a diagram showing the overall structure of a scanning type projection exposure apparatus according to a first embodiment of the present invention.

[FIG. 2] It is a perspective view for schematically explaining a sequence of scanning exposure.

[FIG. 3] It is a partially sectional view showing a detailed configuration around a projection lens system in FIG. 1.

[FIG. 4] It is a block diagram schematically showing liquid temperature control and a liquid supply system according to a second embodiment of the present invention.

[FIG. 5] It is a partially sectional view showing a configuration around a wafer holder and a projection lens system according to a third embodiment of the present invention.

[FIG. 6] It is a partially sectional view showing a configuration around a wafer holder and a projection lens system according to a fourth embodiment of the present invention.

[FIG. 7] It includes a sectional view (A) and a plan view (B) showing the structure of a holder table according to a fifth embodiment of the present invention.

[FIG. 8] It is a schematically sectional view showing the main part of a sixth embodiment of the present invention.

[Description of Notations]

1 … Projection Optical System 1a … Last Lens Surface

7, 8 … Case 7a, 8a … Immersion Liquid

3 … Wafer 3a … Wafer Holder

4 … Inlet 5 … Outlet

6 … Thermoregulator L … Working Distance

10 … Illumination System 12 …Condenser Lens System

14 … Mirror 16 … Reticle Stage

17 … Laser Interferometer System 18 … Motor

19 … Column Structure 20 … Reticle Stage Controller

30 … Base 32A, 32B, 32C … Actuator

33 … Laser Interferometer System 34 … XY Stage

35 … Wafer Stage Controller 36 … Drive Motor

40 … Main Controller 50A, 50B …Thermoregulator

51 … Groove 51 52 … Passage

53 … Pipe 53A, 53B …Passage

55 … Temperature Sensor 60 … Controller

62 … Selector Valve 64 … Liquid Supply Unit

64A … Pump 64B … Temperature Controller

66 … Drainage Pump 66 80 … Sub Lens-Barrel

82 … ZL Stage 83 … Center-Up Pin

84A, 84B … Leaf Spring 85 … Vertically Driving Mechanism

87 … Cover Plate 88A, 88B … Drive Mechanism

90 … Wafer Chuck 91 … Through-Hole

95 … Arm 112 … Piping

113 … Suction Face 114 … Outer Corner Portion

IL … Pulsed Illumination Light AI … Illuminated Area

R … Reticle Pa … Circuit Pattern Area

SB … Light-Shielding Zone PL … Projection Lens System

AX … Optical Axis LGa … Front Lens Group System

LGb … Rear Lens Group System Ep … Projection Pupil

LE1 … Positive Lens Element Pe … Lower Face

CG … Parallel Flat Plate W … Wafer

SAa, SAb … Shot Area SI … Projected Image

WH … Holder Table LB … Wall

LQ … Liquid HRS … Auxiliary Plate

DB … Liquid Sealing Door OL … O Ring

FAD … Focus Alignment Sensor

MRr, MRw … Moving Mirror ML … Reference Mirror

BSr … Reference Beam BSm … Measuring Beam

Sf … Focus Signal Sa … Alignment Signal